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ANATOMICAL OBSERVATIONS ON THE BRAIN AND SEVERAL SENSE-ORGANS OF THE BLIND DEAF-MUTE, LAURA DEWEY BRIDGMAN.

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I.

Through the exertions of President G. Stanley Hall, the brain in question was obtained and was put by him in my hands for description. Several gentlemen whose names will duly appear have assisted by describing the sense-organs. I am under obligation to others for facilitating the work in many ways, and especially to Prof. W. F. Whitney and his colleagues of the Harvard Medical School, Prof. B. G. Wilder of Cornell University, and Prof. C. K. Mills of the University of Pennsylvania, for the privilege of examining specimens in their possession. For the opportunity to consult the literature I am indebted to the exceptional facilities offered by the Library of the Surgeon General at Washington of which I have made much use.

In the study of this case it has been my aim to give as full a description as the material in my hands would warrant, and for this purpose I have applied a large number of tests to the brain, to determine, if possible, whether the peculiar mental existence of Laura Bridgman, which was the result of

her defective sense-organs, has left any trace on her brain, or whether such anomalies as may be observed are sufficiently explained when considered as the direct consequences of the initial defect alone. This is, therefore, a special study in the general field of the inter-relation of brain structure and intelligence. What might be expected to come from the various tests will be discussed under the separate headings, and I shall leave such generalizations as are possible until the special points have been set forth.

Biographical Notes.

By way of introduction, I may be permitted to state some biographical facts that will bear on this discussion. Laura Dewey Bridgman(1)* was born Dec. 21, 1829, in Hanover, New Hampshire, U. S. A. She was the child of Daniel and Harmony Bridgman, who were farming people. The parents(1) are described as of sound health, good habits, average height, slenderly built; the father with a small head, the mother with "not a large head"; both rather nervous; the mother active-minded. Their culture was such as might be found in rural districts like their own at that time. Laura inherited the physical peculiarities of her mother, and her health was delicate. During infancy she was subject to convulsions, but at the age of twenty months her health improved, and she is described as active and intelligent. She had learned to speak several words, and knew one or two of the letters of the alphabet, when, being two years(2) † old, she and her two older sisters, forming at that time the family, were attacked with scarlet fever. The two sisters died. Laura was severely ill; both eyes and both ears suppurated, and taste and smell were impaired. Sight in the left eye was entirely abolished. With the right eye she appeared to get some sensation from extremely large bright objects, up to her eighth year, but after

* The bracketed figures in the text refer to similar figures in the bibliography, where the authority is given in full. In some cases reference is made to the page of the publication cited and this is then bracketed in the text with the figures just mentioned.

† The date of this illness is a matter of some importance. As there is no agreement among the various authors on this point, I have been forced to choose an authority and have naturally taken the dates given by Dr. Howe in his Reports.

that time became completely blind. Two years passed before she recovered sufficiently to sit up all day. At the age of five years she had regained her strength. Speech was lost with the loss of hearing, and when her education at home was renewed, it was by means of arbitrary tactual signs of the simplest sort. She was taught to sew, to knit and to braid, and to perform some minor household duties. On Oct. 4th, 1837, she was brought to the Perkins Institution and Massachusetts Asylum for the Blind, and her education was begun by Dr. S. G. Howe, then director of the institution. She was now seven years and ten months of age, and in the defective condition above described. Dr. Howe ([2–p. 161]) says of her at this time: "figure well formed; nervous sanguine temperament; a large [no measurements have been preserved] and beautifully shaped head, and the whole system in healthy action."

The process of education commenced with the pasting of the name of a common object on the object, the name being in raised letters, such as are used for the blind; then the association of the name and object; then forming the name from the individual letters; and after a long time the letters themselves were learned. It was when she first recognized that the sign for an object could be constructed from the individual letters, that the meaning of what she was doing dawned upon her. From that time on her education became easier, and, indeed, she had in one sense to be held back in her work, as there was danger that her frail constitution would succumb to the too great interest in her studies. It is important to note that at this time she exhibited the various emotions by gesture and facial expression. She was fond of dress and pleased by attention. The lapse of time within the limits of the day and the occurrence of Sunday were correctly noted by her. In the report for 1839 ([2–p. 177]) it is said that she can distinguish between a whole and half note of music, and will strike the notes on the piano quite correctly. (How this interesting test was made, is not quite clear.) A test of her sense of taste at this time showed her capable of distinguishing better between different degrees of acidity than between this and sweetness or bitterness. She appeared at the same time to care rather less for eating than most children of her age.

The sense of smell seems to have been subject to some variations. During the first years of her residence at the institution it was apparently completely wanting, and there was never at any time the slightest tendency to test objects by holding them to the nose. Later (1843) she seemed able to locate the kitchen by the odors coming from it, but this sense does not appear to have ever been of any importance to her. The sense of touch was very acute even for a blind person, and she was sensitive to jar.

Dirt or a rent in her clothing caused her shame. She was familiar with those of her own sex, but distant to men, and was remarkable for her sense of order, neatness and propriety. She seemed capable of discovering the intellectual capacity of those with whom she was thrown, and quickly chose the more intelligent for her companions. Occasionally, too much attention to other scholars, in her presence, aroused jealousy on her part.

She cried only from grief, and the pain from a bodily injury she sought to annul by jumping and excessive muscular motions. So far as could be learned, she did not dream in the terms of her lost senses, and this is what might be expected, since they were lost at so early an age([3]).

She made a number of noises. Francis Lieber studied these with some care, with a view to their bearing on the origin of language([4]). It appears that Laura had some fifty or more sounds by which she was accustomed to designate people whom she knew. They were all monosyllabic. Besides this she laughed much and loud, was noisy at play, and occasionally made other emotional noises which were suppressed by her teachers. In this respect she was similar to most mutes, so-called, who appear to have a variety of sounds at their command.

In a recent article, Mrs. Lamson([5]) states that Laura once uttered the word *doctor* by accident, and her attention being called to this, she subsequently always spoke the word instead of spelling it with her fingers. The same thing happened with the words *pie*, *ship* and several others. These facts are taken to indicate that though so defective, she might possibly have been taught to vocalize, as has been done in some more recent cases. She appeared to keep constantly her

relations in space, and became confused if she lost what might be called "the points of the compass." She was much afraid of animals, and when more than fifteen years of age could hardly be induced to touch a docile house-dog.

When about sixteen she is described as more thoughtful and sedate, though cheerful—a condition which Dr. Howe regards as showing that her age was to be measured by the degree of her mental development rather than by the number of years she had lived. When she was twenty years of age her regular education ceased, and the special reports by Dr. Howe stop at this time.

In 1878, President G. Stanley Hall([6]) made a valuable series of tests upon her. At this time she was found completely blind and deaf, though the sense of jar was well enough developed to enable her to recognize the footsteps and sometimes even the voices of her acquaintances, her common statement being that she heard "through her feet." At this time her sense of smell was such that she could distinguish the odors of some more fragrant flowers, but eau-de-Cologne, ammonia and onions were thus recognized only when quite strong. Contrary to what was stated for an earlier period, she was found least sensitive to bitter and acid tastes, and most sensitive to sweet and salt. It was concluded that out of the four defective senses, taste alone was well enough preserved to materially aid in developing her notion of the external world. A study of discriminative sensibility for two compass points showed a discrimination in her case, from two to three times as acute as that of a seeing person. To temperature, her sensitiveness was not remarkable, and hence the "facial sense," as it is sometimes called in the blind, was not well-developed in her, though she was said to recognize the approach of persons by the undulations of the air. She was found sensitive to rotation, which made her dizzy and gave her a feeling of nausea.

In the course of her life Laura was the author of "a Journal, three Autobiographical Sketches, several so-called poems and numerous letters." The Journal covers a period of about ten years. Dr. E. C. Sanford([7]), who has made a

study of her writings, sums up her mental development as thus indicated, by the statement that "she was eccentric, not defective; she lacked certain data of thought, but not, in a very marked way, the power to use what data she had."

She died at the Perkins Institution, where she had spent almost her entire life, on the 24th of May, 1889, being in her sixtieth year.

Laura excited wide interest because, for the first time in her case, several experiments were tried and questions tested, with unprecedented results. Her case was used for research in matters pedagogical, psychological and theological. But these are passed over, as they lie outside our present scope.

Her defect is often regarded as almost unique. As a matter of fact, if the deficiency of smell and taste is counted with that of sight and hearing, there appear to be few cases like hers; but so small is the educational value of the first two named, that she may be fairly classed with the blind deaf-mutes, in which, for the most part, the state of smell and taste is not recorded. As Prof. Edwards A. Park says in the introduction to Mrs. Lamson's book([1]), there are some fifteen cases recorded of persons who have lived as blind deaf-mutes. Dr. Howe formed his plan for the instruction of Laura from the study of Julia Brace, who was a blind deaf-mute. There were several similar cases at the Perkins Institution during Laura's lifetime, and there are two young girls in that institution now who are defective in the same way. Special descriptions of one or more cases have been given by Mareschal([8]), Fowler([9]), Burdach([10]), Alessi([11]), Sichel([12]), Fuller([13]) and Borg([14]); and Mrs. Lamson, in the current number of the "American Annals of the Deaf,"([5]) mentions a Norwegian girl, Ragnhild Kaata, who is blind and deaf, but having been taught to articulate, can no longer be described as mute. In the same article is mentioned a school in Sweden where five blind deaf-mutes are being instructed. Finally, I may call attention to the fact that in the Census of 1871 for Great Britain there are 111 returns for blind deaf-mutes([15]), while in the 10th Census of the United States, in the analysis of

statistics relating to the defective, dependent and delinquent classes by Wines([16]), there are returned:

Blind deaf-mutes,	256.
Blind deaf-mutes, also idiotic,	217.
Blind deaf-mutes, also insane,	30.

The literature on this subject would probably be found to be extensive if carefully gathered, and the statistics, if taken from all sources, would show a very considerable number of individuals in this class. It is my purpose, however, only to call attention in a general way to this point, as bearing on our subject. Taking the Census of 1880 for the United States, Laura's case could only be compared with the simply blind deaf-mutes—256 in number—and it would need a careful analysis of this group in turn, to show how many cases were strictly comparable with hers. There is good reason to think, however, that a number of such would be found.

I do not know that we are in a position to say from sound data what the effect of loss of the senses—as in Laura's case—is on the mental integrity of the individual, but certainly the proportion of blind deaf-mutes who are also mentally defective is very large. At the same time there is reason to think that the large number of those who are idiotic were either congenitally defective (the idiocy and the other defects having a cause in common), or that they became defective shortly after birth, and were neglected by those in charge of them. Two points came out in a striking manner in looking over these cases as presented in the literature just cited. The first is, the small amount of mental pabulum which serves to keep the action of the mind normal; and second, the late stage (measured in years) at which instruction may be begun with fair hope of success, the nervous mechanism apparently retaining for an unusually long time the impressionability which in the normal person belongs to early childhood.

Physical Data and Report of Autopsy.

On her entrance into the Perkins Institution, some physical measurements were taken, which were unfortunately lost. At eleven years of age her height was 4 ft. 4.7 in. (1.33 M.). Her head measured 20.8 in. (52.8 cm.) in circumference,

along a line passing over the prominences of the frontal and parietal bones. Above this line the head rose 1.1 in. (2.8 cm.), and was broad and full. From the orifice of one ear to the other, the (*shortest*) distance was 4 in. (10.1 cm.), and from the occipital spine (*protuberance?*) to the root of the nose, it was (*shortest distance*) 7 in. (17.7 cm.). The forehead was said to have grown perceptibly larger during the two years preceding ([2–p. 181]). These are the only data that I have been able to find. As nearly as I can learn from those best acquainted with her at the Perkins Institution, her height at maturity was 5 ft. 3 in. (1.596 M.), and her weight, with clothing—98 lbs. avoirdupois (44.45 kilos).

During her residence at the institution, she appears to have had no serious illness up to the time of the one which proved fatal, although often in poor health as the result of over-exertion in her study or from emotional excitement, as for example that caused by the death of Dr. Howe, to whom she was deeply attached. Her final illness lasted about three weeks, and she sank gradually to a painless death—before, it is said, advancing years had perceptibly impaired those faculties which she exercised. The autopsy was performed eight hours after death, by Dr. E. S. Boland, of South Boston, in the presence of several gentlemen. The cause of death is stated as lobar pneumonia. Aside from the lungs, the other viscera appeared healthy save the left kidney, which was slightly atrophied. The encephalon was removed in the *dura* with the eyes attached, and the petrous portions of the temporal bones and part of the ethmoid were also taken out. The cranium is described as symmetrical and of good shape and size; bones thin; diploë slightly marked; but little subdural fluid; the encephalon fitting the cranial cavity closely; *dura* normal in appearance. For the above facts I am directly indebted to Dr. E. S. Boland. The encephalon was not weighed at this time, nor was any further examination permitted. For the next seventeen hours it was kept in a moderately cool place, but not in any fluid. At the end of this time it came into the hands of Prof. W. F. Whitney, who very kindly took charge of it. The specimen was now in such a condition that it was deemed best to cut it in various directions, in order to permit

the hardening fluid to penetrate. Four transverse incisions were made, the first being about 3.5 cm. from the frontal end, and the other three at equal intervals behind it. The depth was such as to open the lateral ventricles in either hemisphere without injuring the *callosum* or basal ganglia. Along the mesal surface of each hemisphere a longitudinal cut was made, extending about the length of the *callosum* and laying open the lateral ventricle on each side. The entire material was then put into several litres of Müller's fluid plus one-sixth its volume of 95% alcohol. This fluid was changed some four or five times in the period between May 25th and July 10th, at which time the specimen came into my possession. The eyes were then separated from the encephalon, and they with the portions of the bones, were treated by themselves. The encephalon was hardened for some three months more in 2½ % potassium bichromate; kept for a long time in a dilute solution of the same; finally washed out, hardened in 95% alcohol, and preserved in 80% alcohol. The majority of the measurements were made while it was in the 2½% or dilute potassium bichromate.

Photographs and Models.

In studying the encephalon, it was necessary to make those observations which required least dissection first, and so proceed that the different portions should retain their normal connections as long as possible. The results, however, under any head, will be given without reference to the order in which they were obtained. As the complete examination required ultimately a dissection of the encephalon, with consequent loss of form, I first had it carefully photographed, the encephalon being taken from six points of view, and then the mesal surface of each hemisphere taken alone. The entire exposed surface, with the exception of that covered by the cerebellum, is thus represented, and this latter surface was sketched. It would be extremely desirable to have these various views adequately represented, but since the means for so doing are not at present at my command, I have preferred to await some future opportunity rather than to represent them now by some method of doubtful value.

It was further extremely desirable to have an accurate model of the encephalon. The character of the specimen, the cuts in it and the method of preservation were all against any device for taking a direct cast of it. I was, therefore most fortunate in securing the co-operation of Mr. J. H. Emerton, of Boston, whose skill in modelling such objects is well known. He made an accurate clay model of the specimen; from this a glue mould was taken, and a number of plaster casts were at once made from this mould, before it had time to undergo any distortion, the original clay model being preserved for comparison. The results are entirely satisfactory, and we have now what is equivalent to a good cast of this specimen. In making the model, the cuts in the hemispheres were not represented, and thus the general appearance was improved without any material loss in accuracy.

Envelopes and Vessels.

Within the limits of this paper I shall have to deal exclusively with questions relating to the gross anatomy of the specimen.

Dura: Sinuses filled with blood. Normal in appearance. It was incomplete at several points on the ventral aspect of the hemispheres and the cerebellum was completely exposed, the *tentorium* and *falx* being both present. This somewhat defective membrane, including *tentorium* and *falx*, weighed, after hardening by the method above described, washing out in water, and being pressed between filter papers, 54.4 grms. No data for comparison have thus far been found.

Pia: The vessels were filled with blood. To all appearance it was normal. The adherence to the occipital regions appeared uncommonly strong, even making allowance for the close adherence which is normal for this region. The *pia* from the entire encephalon with the choroid plexuses, but without the basal blood-vessels, was treated like the *dura* and found to weigh 25.1 grms. The quantity of the *pia* obtained was estimated at about .8 of the total. That supposition being correct, the total *pia* would weigh 31.4 grms.

What the influence of the hardening process is on the weights of the membranes, *dura* and *pia*, is not known, but

it is presumptively slight. Giacomini([17]) has made observations on the weight of the *pia* and cerebro-spinal fluid, which I give. It is to be remembered that we have no means of knowing the quantity of the fluid in our case, though the autopsy report states that there was apparently little at that time. Confining himself to the cerebral hemispheres, which were weighed separately, Giacomini found in 30 normal brains the weight of *pia* and residual cerebro-spinal fluid (the bulk of the fluid having escaped on the hemisection of the cerebrum, and having been then collected) to be from 5 to 5.5% of the weight of the hemispheres. Where the vessels of the *pia* were congested, the percentage might rise to 6 or 6.5%. According to Calori, quoted by Giacomini, the weight of the *pia*, blood and cerebro-spinal fluid for the whole encephalon is 14% of the entire weight. This figure seems to Giacomini too high. Huschke([18]) calculates that removal of the *pia* and choroidal plexuses from the cerebral hemispheres alone diminishes their weight by 50—60 grms. (This diminution is plainly in part due to loss of fluid consequent on removal of the *pia*). Bischoff([19]) gives 25—40 grms. for the *pia* of the cerebral hemispheres alone. Bastian([20]) gives 21—28 grms. for the *pia* of the entire encephalon. Where the brain is sliced and allowed to drain for 1—2 hours, according to the method of Thurnam([21]), there is, according to Bastian, an additional loss of 28—56 grms. Bischoff([19]) gives further figures from Weisbach, Hagen and Marshall, which I have not been able to verify, and therefore omit.

There is here hardly sufficient data on either hand for the purposes of comparison, but the assertion may be fairly made that the *pia* in our case shows no marked peculiarity. Unfortunately, the conditions do not permit us to follow Giacomini's ([17]) suggestion, and infer from the weight of the *pia* its relative thickness.

Volume of Encephalon.

On Aug. 13, 1889, while the specimen was still in 2½% potassium bichromate, an effort was made to obtain the volume. The encephalon (deprived of *pia*) was put in a large jar filled with water. On the water floated a cork, in the centre of which a long pin was stuck vertically. A ruler

laid across the top of the jar formed a line to the level of which the top of the pin rose when water was poured into the jar. The encephalon being in the jar, water was then added until the head of the pin was level with the edge of the ruler. The encephalon was next removed, with all precaution as to drainage, etc., and the quantity of water was measured which had to be added to that in the jar in order to bring the pin-head to the same level. Two determinations were thus made:

Determination 1 gave volume	= 1385 c.c.
" 2 " "	= 1381 c.c.
Mean,	= 1383 c.c.

This figure, 1383 c.c., I have taken to represent the volume under the conditions stated.

The cuts in the specimen were such that there is good reason to think that the lateral ventricles were filled by the fluid in which it was immersed. The method, I am aware, was rough, but was the best at my command at that time. The most important correction to be made is that for the change of volume of the specimen due to the process of hardening to which it had been subjected. On this point some experiments have been made, which are not yet ready for publication. I shall, however, use the facts obtained without further proof, trusting that I may soon be able to give evidence of their correctness. To save any repetition, it may be here stated that the experiments just mentioned relate to the volume, weight and specific gravity of the encephalon, and will be introduced under their proper headings without further remark.

If an encephalon is treated like that of Laura (from six to twelve hours after death), the conditions for its preservation in the mean time having been good, it will show an increase equal to about 25% of the initial volume. This, however, takes place only when the specimen is fairly fresh. When it is not fresh, but still hardens slowly and incompletely, the increase may be about 2% of the initial volume. In our case it is a fair estimate that one-third of the initial mass of the encephalon is hardened so as to have undergone an increase of but 2% in volume, while the other two-thirds may

be considered to have undergone the full enlargement of 25%. Making use of the above percentage for correction, the volume observed would be $\frac{88}{75}$ of the initial volume, or

$$\frac{1383 \times 75}{88} = 1178 \text{ c.c.} = \text{initial volume.}$$

The value of this figure is simply that of the best approximation which I can now make.

Weight.

At the same time that the volume was taken the specimen was weighed. The weight thus obtained (on balances weighing to 0.1 grm.) was 1389.5 grms., the *pia* being completely removed. The hardening of the specimen had caused it to increase in weight about 22% for those parts which were well hardened. The same conditions determine the amount of this increase in weight that determine the increase in volume, and when the specimen hardens imperfectly the increase in weight is a trifle less than 2%, but may be called 2% for the present purpose. Supposing, as before, that two-thirds of the initial brain-mass have increased 22% in weight, and one-third 2%, we have, 1389.5 grms. = $\frac{173}{150}$ of the initial weight, or

$$\frac{1389.5 \times 150}{173} = 1204 \text{ grms.} = \text{initial weight.}$$

Any criticism which can be applied to the volume can also be applied to the weight as thus deduced.

The initial specific gravity of this encephalon or any portion of it is not known, but if we deduce it from the calculated weight and volume, it is 1.022. This is a smaller figure than Bischoff(19) found. For female brains, his figures are from 1.0305 to 1.0478. The determination of the weight in this case is, in my opinion, less subject to error than the determination of the volume. If we consider a brain of this weight to have either of the extreme specific gravities given by Bischoff or one represented by their mean, we have for a brain weighing 1204 grms.,

sp. gr.	1.0305	giving a volume		= 1168 c.c.
" "	1.0391	"	"	= 1158 c.c.
" "	1.0478	"	"	= 1149 c.c.

Thus furnishing figures for the volume which are 10, 20, and 29 c. c. below those first calculated.

Further manipulation of these figures would be of little value. It is concluded, however, that the probable weight of Laura's brain was somewhat over 1200 grms., and that the probable volume was about 1160 c. c.

The mean weight for the English and European female encephalon is variously given. Bischoff([19]), 1244.5 grms.; Tiedemann, 1275 grms.; and Huschke, 1272 grms. Schwalbe([22]) gives 1245 grms., as deduced from a composite table of weights. This table further shows that out of the 339 cases which it includes, 283 have a weight between 1100 and 1420 grms., and the majority (two-thirds) of these in turn have a weight between 1160 and 1330 grms. Our specimen, therefore, falls within these last limits, but somewhat below the mean, 1245 grms. The figure which we have obtained will not warrant any discussion of the weight in relation to other conditions of age, body-weight and height. It may nevertheless be pointed out that our specimen had probably not undergone any important loss of weight due to advancing age, and that furthermore it is possible that the figures which have led to the generalization that at about sixty years the encephalon begins to lose in weight, may perhaps, as has been suggested, be as well explained by some relation not yet investigated, between brain weight and longevity.

Of the subdivisions of the encephalon, the cerebellum alone was weighed separately. It was separated from its connections by cutting through the peduncles as close to the hemispheres as was practicable. The portion thus removed weighed 163 grms. The increase in weight due to hardening is about 27% for the cerebellum, which would make the initial weight 128 grms. Taking the weight of the entire encephalon as 1204 grms., then the cerebellum is 10.63% of the entire weight. This percentage is exactly that found by Weisbach and 0.17% lower than that found by Meynert, as quoted by Schwalbe([22]). It serves to show that there was nothing very peculiar in the weight relations of the cerebellum to the rest of the encephalon in this case. The

other weights which are usually recorded could not be taken, because further dissection of the brain was impracticable in view of the other observations to be made on it.

Linear Measurements.

On Nov. 4, 1889, the following measurements were made:

Greatest length of left hemisphere,	178 mm.
" " right "	**180** mm.*
The maximum width of cerebrum,	153 mm.
The maximum height of cerebrum,	129 mm.
The longest perpendicular distance, taken on the mesal aspect of each hemisphere, from the line measuring the length of the hemispheres to the dorsal surface, is in this case the same for both hemispheres,	73 mm.
The encephalon being in the normal position, the distance between a perpendicular plane just touching the tips of the temporal lobes and one just touching the tips of the frontal lobes was found to be	57 mm.

Schwalbe's([22]) figures for similar dimensions in the female brain are, greatest length in the majority of cases, from 150 to 160 mm., the limits being 142–189 mm. (Huschke). The mean breadth is given at 140 mm., whereas the height is given at 125 mm. For the longest perpendicular as above described, and the distance from the tip of the temporal to the tip of the frontal lobes, I find no data that are comparable. For comparison on the last measurement, I have used three male brains which were hardened in bichromate and alcohol in the usual manner, and which are nearly the same length as our specimen, (from 2 to 11 mm. longer). In these the temporo-frontal distance, if I may so call it, was respectively 47, 41 and 51 mm., as compared with 57 mm. in Laura.

Of course, the swelling of the encephalon due to hardening has increased all three diameters, and so the figures given for Laura cannot be compared with those from Schwalbe until some correction has been made in them. Such correction I am at present unable to make. Assuming, however, that the enlargement along the several diameters is proportional to their initial length, we can make the calculation for the

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* Where similar measurements for the two halves of the brain are given, the larger figure is in heavier type. It is hoped that this device will render the comparison of the two sides easier.

cerebral index, the mean length being taken as 179 mm., and breadth 153 mm. The so-called cerebral index, obtained by dividing the latter by the former, equals 85+, showing the cerebrum to be markedly brachycephalic. The excessive temporo-frontal distance appears plainly to be due to deficient development of the temporal lobes.

General Description of the Encephalon.

In order to give some data for the control of the foregoing measurements, a general description of the specimen will be useful. To the medulla was attached a piece of the cord which extended 17 mm. from the superficial caudal termination of the decussation of the pyramids. This length was about that usually obtained where the cord is cut through the *foramen magnum*. The shape of the specimen was well preserved, owing to its having been hardened in the *dura*. The angle between the stem and cerebrum was approximately normal, and the relation of the cerebellum and hemispheres therefore but little disturbed. The hemispheres overlapped the cerebellum slightly. The vessels forming the circle of Willis were certainly not large. Of the internal carotids the right was the larger, but only slightly so, and the posterior communicating arteries were small, even in proportion to the other vessels.

In passing now to the several subdivisions, no effort will be made to give a complete description, for the nature of the specimen is not such as to demand that, and all exact measurements will be left until the parts are studied histologically.

Medulla and Pons.—The nerves from this region were identified, except the spinal accessory, which could not be found, having been probably pulled away in removal of the specimen. Here, of course, it is the *glossopharyngeus*, the *acusticus* and the *abducens* associated respectively with the sense of taste, of hearing, and the external rectus muscle of the eye-ball, that are of special interest. These appeared somewhat reduced in size, though all the cranial nerves were small. On the ventral aspect of this region, neither the olivary bodies nor the pyramids were prominent. The anterior

median sulcus between the pyramids was well marked, as was the ventral depression on the *pons*. On the lateral aspect, the *corpora restiformia* appear well developed. On the dorsal aspect, the floor of the fourth ventricle was seen to be clearly marked. There was a well developed *ligula* and *obex*. The nuclei of the *columnæ graciles* made evident swellings in the course of the dorsal columns of the cord, those of the column of Burdach being less marked. On the floor of the ventricle, the *alæ cinereæ* and *trigona hypoglossi* were very evident. The *striæ acusticæ* or *medullares* were particularly clear. The point is of interest, since the *striæ* are looked upon as part of the auditory path in this region. A more detailed description of them will be given later.

Cerebellum.—As we have seen, the cerebellum has thus far offered no peculiarity. The peduncular connections were as usual, and a sagittal section shows the *arbor vitæ* with the characteristic sub-divisions. In the general conformation, there was nothing to excite remark.

Mid-brain.—The oculo-motor nerves were, perhaps, a trifle small. The *trochlearis* was not found. On the ventro-lateral surface, a search for *tractus peduncularis transversus* of v. Gudden([23]), which appears to have some connection with visual apparatus, was unsuccessful. However, it must be remembered that this tract is not always superficial in normal individuals, and therefore failure to detect it is not proof that it has degenerated. On the dorsal aspect, the *frenulum* was well marked. The posterior pair of the *corpora quadrigemina* was rather small, but well rounded and both alike. The median groove, the transverse groove separating them from the anterior pair, and the *brachia*, were all well marked. The anterior pair of the *corpora quadrigemina* were much flattened towards the middle line. *Brachia* not evident.

As the result of the cuts necessarily made to allow the entrance of the hardening fluid, and the failure of this region to harden, subsequent dissection has yielded but small results. Of the condition of the *corpora geniculata* on the right side, nothing can be said. On the left side the *corpus geniculatum internum* can alone be described, and this was comparatively large and prominent.

Inter-brain.—On the left side of the specimen the *pulvinar* had been preserved, and there it was reduced in all dimensions, and but little arched; on the other side it had broken away and could not be described. The caudal portion of the third ventricle was large. There was a well developed median and posterior commissure. The general lack of development in this inter-thalamic region is not shared in by the pineal gland and its connections, the *habenulæ* and *trigona habenulæ*, which were disproportionately enlarged—an enlargement which is probably due to the removal of pressure from the surrounding structures. Turning now to the ventral surface, the *corpora mammillaria* and, it may be added, the *fornix*, were normal. About the pituitary body, there was nothing peculiar, but the *infundibulum* is prolonged ventrad to an unusual degree, and is bounded on either side by the greatly shrunken optic tracts. The relations of the anterior commissure in view of its connection with the olfactory centres would have been interesting, but the specimen did not show this commissure, owing to imperfect preservation.

Before proceeding to the *callosum* and the hemispheres, it may be well to consider what we should expect to find in these portions. There is no suggestion in this case that would lead us to anticipate appearances such as are recorded for microcephalic, criminal, or low-type brains belonging to the least civilized races. Neither is the case to be associated with those in which the defect or arrest of development was due to causes originating within the central nervous system. There was not the slightest indication of abnormal mental action, and therefore the brain would not be expected to resemble that of the insane, if for the moment we admit that the brains of the insane show gross peculiarities. What we have is the brain of a normal person who lost at about two years of age the senses of sight, hearing, smell and taste, through injury to the peripheral sense-organs, but who remained mentally balanced throughout a long life, though under conditions which would favor mental derangement, had the tendency to it existed. This loss would have but a moderate power to destroy what was already formed in the brain, though it would do so to some extent.

The chief effect would be to retard the further development of those portions which represented the lost senses, but even here the hereditary laws of growth would act to some extent independently of the modifying conditions which existed in such a case.

As a point of departure, then, it would be interesting to know what was the state of development of an average female brain at the commencement of the third year of life. If we take 1245 grms. as the average weight of the female encephalon, we find that at the commencement of the third year or end of the second, the average weight is about 920 grms. for females. [See Boyd's tables quoted by Schwalbe([22]), and Bischoff's([19]) table of five observations, made up from those of Huschke and Sims. The figures quoted by Vierordt([24]) are not available, because no distinction of sex is made, and, as is well known, such a distinction exists at birth and even in the fœtus.] If 920 grms. is the true figure, then at this age the weight of the encephalon is about three-fourths that of the adult. As the specific gravity is somewhat less, its volume is proportionately a trifle greater.

On the relations of the nerve-cells and fibres, not much can be said that is satisfactory. Whether we have the elements all formed at birth, and they undergo simply an increase in size during the subsequent processes of growth, so-called, or whether we have new elements formed after birth, is a question for the decision of which the evidence is as yet scanty. Schiller([25]), at Forel's suggestion, determined with due precautions the number of nerve-fibers in the *oculo-motorius* of kittens at birth, and cats at the end of the first year, and found practically the same number in both cases. In this animal and this nerve the number of fibers, then, does not increase after birth. In man, however, the period of helplessness and development after birth is comparatively long, and Below([26]) has found in animals that the cortical cells are less developed in those born helpless than in those born in a more mature state. Incompleteness in the development of the central nerve-cells would favor the idea that they might still undergo multiplication after birth. As a matter of fact, the development of the cortical cells in the human fœtus is incomplete

at birth (Obersteiner[27—p. 367]), and the development of medullated fibers far more incomplete. The medullation of fibers is continually going on during the early years of life, and there is evidence that it is for the most part completed about the eighth year. For those who hold that practically the number of elements is fixed at birth, the increase in the size of existing elements, and especially the medullation of the fibers, are the causes of the enlargement of the encephalon. If such is the case, however, and Galton's([28]) measurements on the heads of Cambridge undergraduates mean what he takes them to mean, *i. e.*, brain growth, then the process of medullation or enlargement, or both, must continue in some cases up to the twenty-fifth year.

If we turn now to the sulci and gyri, we find all the important ones present at birth [Ecker([29]), Rüdinger([43])]. At that time, the cerebral surface is marked in a typical manner, and according to Ecker the asymmetries which occur in the sulci are caused by the later development of accessory sulci. What the history of these accessory sulci may be, has not, I believe, been studied, and how far they may be developed during the first two years of life, is therefore an open question; but *a priori* one would imagine that the earliest years of life would be the time when they would appear. Be that as it may, it seems highly probable that the relations of the primary and secondary sulci are fixed to a large extent at birth, and that subsequent development has but a slight influence in altering these relations.

In the child at birth, and during the first years of life, the relative development of the several lobes of the brain is not the same as in the adult. Designating the lobes as occipital, temporal, insular, parietal and frontal, Bischoff([19]) states that it is the last two which develope most in later years, and of these the parietal undergoes the greatest enlargement; but the observations on this point are few.

Applying the above conclusions to our case, we may describe Laura's brain at the age of two years as having about three fourths of its adult weight, the cells of the cortex being fairly developed, whereas the medullation

of the fibers was incomplete to a considerable degree. The primary and secondary sulci were all present, and probably some of the accessory sulci also; and the parietal and frontal lobes were less developed than they should be in the adult. If the *callosum* is commissural for the different portions of the cerebral cortex, we might expect it to accompany the cortex in development. In the absence, so far as I am aware, of explicit observations on this point, we may assume the *callosum* well developed at this age.

On such a brain as we have described, what would be the effect of a lesion, like that which occurred in the case of Laura? The nerves and their primary centres would show degeneration, and later some atrophy, then after the lapse of time, arrest of development, in so far as they were incompletely developed at the date of the injury. In the cortical regions, so far as they might be affected, we should probably expect some arrest of development which would show itself on gross examination, and certainly some histological indications of arrest and possibly degeneration. Further, as one result of the limitation in mental activity due to the great defect in the senses, a general appearance of immaturity might be anticipated, while if certain lobes were affected more than others, a disproportion in development as compared with the normal would result. It seemed advisable to make some analysis of the case at this point, in order that no ungrounded expectation of striking anomalies might be cherished, and it will be the chief purpose of the following pages to show in how far actual observations bear out the views above advanced.

Callosum.—The *callosum* was well developed. On the surface exposed by a sagittal section dividing the two hemispheres, the distance of a straight line between the extreme points was 82 mm., while a line following the dorsal curve and joining the same points, is 87 mm. long. The height or thickness, as one chooses to call it, always measured vertically (the hemispheres being in the normal position) is 22 mm. at the rostral end, 12 mm. in the middle, and 15 mm. at the splenial end. The area of surface exposed by the section was 1172 sq. mm. The linear measurements exceed somewhat those given by

Krause(30—Bd. 2, p. 965), especially those for the thickness, but I am not sure that mine were taken in the same way as his were; and furthermore, his apply to the fresh specimen, while this was swollen by hardening. Comparison with other specimens hardened in potassium bichromate, shows these figures nevertheless to be large. From gross examination, therefore, the *callosum* appears to have developed completely.

Cerebral hemispheres.—On looking at the hemispheres, the general shape appears normal, but they are somewhat flattened at the occipital pole. The temporal lobe is comparatively small, the tip being thin, and on the orbital surface of each hemisphere at the cephalic end is a marked conical elevation of the general surfaces with the apex directed ventrad. This elevation appears on either side of the median line, just in front of the point where the *sulcus olfactorius* terminates. As the formation is not usually described, and is only faintly suggested in most brains, it is probably an anomaly due, in this case, to the failure of the orbital plates of the frontal bone to develop in the usual manner, thus leaving more of a depression in the bone at this point than ordinarily occurs. To this depression the brain has accommodated itself, with the result of producing the appearance described. When viewed from above, the general effect was quite similar to the typical female brain, as depicted by Wagner(31), the chief difference being that our specimen was not quite so pointed in the frontal region as Wagner's plate of the female brain, and had the gyri in the occipital region in less relief. The gyri were for the most part widely separated from one another, especially in the frontal and parietal lobes whereas in the occipital they tended to be close together. In general, the gyri were large, but little interrupted and moderately sinuous, and the insula was more exposed on the left than on the right side. The typical arrangement of the gyri was easily followed, and the two hemispheres quite symmetrical in their markings. The symmetry of the hemispheres, the continuity and size of the gyri, may be taken as indicating an average or perhaps less than average development in these respects. Such a statement has, however, so little foundation that is measurable and exact, that it will be best to leave it in the form of a

mere suggestion. There is some departure from symmetry in the two hemispheres, where, on the mesal surface of the occipital region, the ventro-caudal portion is smaller in the right hemisphere. This is shown in an exaggerated way in Plate II, Fig. 4.

As illustrating the general development of this specimen, I introduce here several measurements which were made while the brain was in potassium bichromate.

Taking the smaller angle which the *fissura centralis* makes with the middle line, following the method of Eberstaller([32]), it was found to be,

For left hemisphere,	65°.
For right hemisphere,	61°.

This is smaller than is usually stated. Wilder([38]) gives 67° as an average, and Eberstaller 70°–75°.

If we take the entire length of the mesal edge of the hemispheres measuring from the *trigonum olfactorium* to the occipital pole, and then the distance from the *trigonum olfactorium* to the point where the *fissura centralis* reaches the mesal surface, we obtain the following figures:

Left hemisphere, entire distance,	334 mm.
Right " " "	331 mm.
Left hemisphere, distance to *fissura centralis*,	214.5 mm.
Right " " " "	216 mm.

This, reckoned in per cent. of the entire distance, gives the last distance or extent of frontal lobe along this line, as

Left hemisphere,	64+%.
Right hemisphere,	65+%.

Eberstaller([32]) gives for the female brain, 66%. Our figures, therefore, approximate closely to his average. Measuring the *fissura Sylvii* on each side from the point where it gives off the anterior *rami* to the point where it gives off the *ramus posterior ascendens*, it was found,

For the left hemisphere,	53 mm.
For the right "	52 mm.

This makes it shorter than the average figures for females found by Eberstaller([32]), which was 56.5 mm.

Among these figures, one set (namely that for the position of the mesal end of the *fissura centralis*) is in

percentage, and that agrees fairly well with the results of other authors. It may be presumed, then, that in hardening the encephalon has not undergone much distortion. If that is true, then the small angle of the *fissura centralis* with the middle line is probably a true relation. Despite the enlargement of the specimen, the length of the *fissura Sylvii* as measured is under the average, but the relations of the two sides are as Eberstaller found ; that is, the left is the longer.

The condition of the ventricles was not easily made out, owing to the state of the specimen and the cuts in it, which somewhat disturbed the connections here. The lateral ventricles were certainly not large. The descending *cornua* were well developed, but the right posterior *cornu* terminated 47 mm. in front of the occipital pole. In the left hemisphere it reaches to within 42 mm. of the occipital pole, and there is a well developed *calcar* which was not observed on the right side.

Description of the Surface of the Hemispheres.

As was stated earlier, it is not my purpose to describe in detail the cerebral surface in this case,—as good plates would give a far better idea than could be obtained from the text,—so that on this occasion I shall be content with some outline figures and a description of those regions which may be regarded as important. The four representations of the specimen were drawn from photographs by means of a pantograph. From these drawings the plates were made by one of the photo-engraving processes. In the figures those sulci which are more constant are put in with a heavy line, whereas the others are in light lines. In the case of the fissure of Sylvius an approximate presentation of the amount of separation of the gyri has been attempted. In the description I shall follow Eberstaller(32, 34) in most points and also adopt his nomenclature.

Frontal Region.—In Figures I and II, the *sulcus frontalis medius*, *f* 3, is clearly marked, thus giving the four frontal gyri, (by sub-division of the *gyrus frontalis medius*,) which the more recent authors are agreed is the normal condition of the frontal lobe. [Eberstaller(32), Wilder(33),

Giacomini([17]).] To be noticed on the left side is the union of the *sulcus frontalis inferior*, *f* 2, with the *sulcus fronto-marginalis*, *fm* 3, which appears somewhat unusual. Further, on the same side the *ramus anterior horizontalis fissuræ Sylvii*, *S* 3, runs into the *sulcus fronto-marginalis*, *fm* 1, but at the junction there is a vadum or shallow, (see Wilder, [33]) which clearly marks the usual limits of this *ramus*. Aside from these points the fissuration of both frontal lobes is quite typical. Directing attention to the *gyrus frontalis inferior* we find it well defined laterally and frontally, but as is usual, poorly defined on the orbital surface. In its entirety that of the left does not differ much from that of the right hemisphere, but there are some differences in detail. Dividing the opercular portions into the *pars orbitalis* ventrad of *S* 3; *pars triangularis* between *S* 3 and *S* 2; *pars ascendens* between *S* 2 and *d*: and the *pars basilaris* between *d* and *pci*, we find the *pars basilaris* much less well developed on the left side, being especially deficient in its ventral portions. The *pars ascendens* is deficient throughout on the left side while the *pars triangularis* is somewhat better developed on this side than on the right. A comparison of the orbital areas is not practicable in this case. It should be added that, on the left side not only is the exposed surface of the *pars basilaris* and *pars ascendens* smaller, but both these are sunken below the surrounding gyri; the former completely and the latter in its ventral portion, the frontal edge of the *gyrus centralis anterior* forming a slight operculum over the *pars basilaris*.

It is our purpose of course to determine whether these features of the left side can be properly brought into connection with the very limited power of articulate speech possessed by Laura. There is good ground for the view that in right handed persons it is the portion of the *gyrus frontalis inferior* of the left side between the *ramus anterior ascendens fissuræ Sylvii*, *S* 2, and the *sulcus præcentralis inferior*, *pci*, that is the centre for articulate speech. So far as known Laura was right handed. According to Eberstaller([32—p. 104]), the *pars basilaris* may often be sunken, but in such cases, where the brain is normal, the *pars ascendens* overlaps and more or

less conceals it. In this case no such overlapping occurs. Several authors have called attention to the value of the comparison of the two hemispheres of the *same* brain where a lesion was suspected on one side, and judged by that test we certainly have defective development of this gyrus on the left side. A variation, however, which seems to me of considerable importance, is the direction of the *sulcus diagonalis*, *d*. One characteristic of this sulcus is that in the normal brain its dorsal end lies further caudad than the ventral end. On the left side in Laura this direction of the sulcus is reversed, the ventral end being further caudad and to all appearance it occupies this anomalous position because the ventral portion of the *pars basilaris* has failed to develop. On the right side it has the normal direction.

In this connection the exposure of the *insula* is significant. I estimate this exposure for Laura:

On the left side,	128 sq. mm.
On the right side,	46 sq. mm.

That is, the surface of the *insula* exposed on the left side is nearly three times that exposed on the right. In looking at the collection of brains in the museum of Cornell University—a collection which has been gathered by Prof. B. G. Wilder,—I found no exposure of the *insula* which approached even that on the *right* side in Laura, save in the *left* hemisphere of a negro (catalogue number, 322), in which the exposure was somewhat less than on the right hemisphere in our case. Of course the absolute relations of the specimens have at present no value since the Cornell brains were hardened in alcohol and therefore had undergone some shrinkage. It may, however, be permissable to conclude that on both sides the exposure of the *insula* in Laura was large, and that on the left side it was much larger than on the right.

Exposure of the *insula* may be considered in general as characteristic of incomplete development (Rüdinger[35]). According to this test, then, there is here a general lack of development which is most marked on the left side. This exposure is due, however, only in part to the small size of the *gyrus frontalis inferior* which contains the presumptive speech centre, and to which we have hitherto

specially attended. Rüdinger[35—p. 45] describes for mutes that have lost the power of speech as the result of deafness and who are otherwise normal, certain slight abnormalities of the speech-centres—but seems surprised that they are not more marked. Without entering into any detail it is evident that the variations in his cases and in that of Laura are similar, and Zuckerkandl[36] also notes as defects in the development of the speech-centre some that we do not find here, but among those that we do find, he mentions the depression below the general surface of the *pars ascendens* and *basilaris*, the hiding of them by surrounding gyri, which thus form an operculum at this point, the exposure of the *insula* and failure of the tip of the temporal lobe to attain its full size. Zuckerkandl[36] has also something to say with regard to compensatory development on the assumption that such compensation may be physiological as well as morphological. Whereas the *pars ascendens* and *basilaris* are less well developed in the left hemisphere in Laura, if the *pars triangularis* of the left side is compared with that of the right it is found to be somewhat larger. It might be urged that this better development of the *pars triangularis* indicated that it had taken on some of the functions of the undeveloped portion. At the moment I am aware of no positive evidence in favor of such a transfer of function and hence do not consider the objection important. Closely associated with this region is the *insula*, but the discussion of that will be deferred until we consider the cortical development of the brain. From what has been said, then, I conclude that the centre for articulate speech in this case shows some defect, which is most naturally explained as arrest of development. The nature of this arrest will be brought up when we come to the histology of the region.

Occipital Region.—We next turn to the occipital region which is represented in Figs. III and IV. The occipital lobe, and specially the *cuneus*, in man, appears to be the cortical centre for vision,—but just what the limits of the occipital lobe are, and how much of this area is specialized as a visual centre, are not precisely determined. Ecker's[37] description of the occipital lobe has not been found satisfactory by later au-

thors and several attempts have been made to improve on his account. Here I follow Eberstaller's description([34—No. 18]). According to him the occipital lobe is best considered as that portion of the hemisphere enclosed between the *fissura calcarina* (*ca*), the *sulcus parieto-occipitalis* (*p. o.*), the *sulcus occipitalis anterior* (*occ. ant.*) and the *sulcus occipitalis lateralis* (*occ. lat.*). The *sulcus occipitalis anterior* is the homologue of the "ape fissure" of the authors. The gyrus between the mesal end of the *sulcus occipitalis anterior* and the *sulcus parieto-occipitalis* is the *gyrus annectans superior*, while that between the lateral end of the *sulcus occipitalis anterior* and the *sulcus occipitalis lateralis* is the *gyrus annectans inferior*. The complete enclosure of the area must be to some extent artificial, but I shall make it by joining the several sulci with one another at the points where they come nearest together, using the two ends of the *sulcus occipitalis anterior* and the caudal end of the *fissura calcarina* as points from which to start the limiting lines. Of the accessory sulci within this area I have at the moment nothing to say.

The left hemisphere, Fig. III, shows a typical arrangement of the sulci bounding this lobe. On the right side the arrangement is similar, but the *sulcus parieto-occipitalis* does not show on the dorsal surface and hence there is nothing to match that sulcus on the left side. On the right, also, the whole occipital region is smaller as shown by the principle outlines, and just laterad of the most caudal end of the *sulcus occipitalis anterior* is a small group of very shallow sulci which appear hardly deeper than vascular grooves, but which section of the region shows to be true sulci.

The smaller size of the region on the right side and the peculiar sulci just mentioned are the principal points which suggest defective development, as the failure of the *sulcus parieto-occipitalis* to appear on the dorsal surface is not so uncommon in normal individuals. At the same time the fact that this same sulcus is well developed on the left side while it is poorly developed on the right is suggestive when taken in connection with the defects already noted. The gyri of this region are all rather narrow and closely pressed together, thus rendering the intra-lobar sulci inconspicuous. Eberstaller

([34–No. 19]) notes that the length of the arc from the occipital pole to the point where the *sulcus parieto-occipitalis* cuts the edge of the mantel is to the entire arc, *i. e.*, to the *trigonum olfactorium* (see p. 315), as 1 to 6. Measured on the left side in Laura it is 1 to 6.1, and on the right it is 1 to 6. This for our purpose is not so significant as the arc between the caudal end of the *fissura calcarina* and the point where the *sulcus parieto-occipitalis* cuts the edge of the mantel, which is,

On the left side,	50 mm.
On the right side,	29 mm.

Showing the great reduction in that measurement of the *cuneus* on the right side. Further, whereas the arc of the *præcuneus* and that of the *cuneus* are about the same length on the left side—a condition of things which is normal,—on the right side that of the *præcuneus* is much longer than that of the *cuneus*. These relations are shown in Fig. IV, where, as can be seen, one cause of the reduction in size of the *cuneus* is its apparent displacement dorsad of the *fissura calcarina*. In the left *cuneus* I find nothing peculiar to describe. In the right side the *sulcus parieto-occipitalis* may be considered to branch just below the letter *p*. The *ramus* marked *p.o.* runs dorsad towards the edge of the mantel, but never reaches the dorsal surface, as the bounding gyrus has its concavity ventrad and its convexity dorsad. The other branch, running almost vertically in Fig. IV, appears to unite with the *sulcus* which, lying cephalad to the *sulcus parieto-occipitalis*, represents that described by Eberstaller([24–No. 18]) as a branch of the interparietal, and by Wilder([38]) as the cephalic stipe of his *fissura paroccipitalis*. The union is apparent only, and is caused by the extension caudad, in the form of an operculum, of the præcuneal wall that bounds these sulci. On removing this operculum, the *sulcus parieto-occipitalis* is seen to be represented by the sulcus marked *p. o.* alone and to have undergone something of a bend with the concavity caudad, at the point of apparent branching, but the relations with the *fissura calcarina* are normal. The appearance here is somewhat further complicated by a considerable development of the accessory sulci on the mesal surface. So far as we have gone, therefore, the right *cuneus* is less well developed than

the left. It will be recalled that we also found the posterior *cornu* of the left side in better condition than on the right. From these facts it appears that the right occipital lobe shows several anomalies which when all are taken together indicate that the arrest of development has been more marked on this side. It will be remembered that up to her seventh year Laura was somewhat sensitive to light in her right eye while she was completely blind in the left. That sensitiveness meant the preservation of a certain portion of the retina in the right eye for some five years longer than in the left. The conservative value for the nerve centres of even such weak stimuli has long been recognized, and it is but natural therefore that the occipital lobe chiefly connected with the right eye should be better preserved than the other whose development was presumptively arrested earlier and during the years most important for growth.

Temporal Lobe.—This is disproportionately small and alike on both sides. The failure to develop appears to affect most of all the tip. In Laura's case I have not discovered anything that seemed to deserve study as an anomaly, so far as the gross anatomy of this region is concerned, and I can present nothing on the cortical centre for hearing, on the assumption that that centre is in or about the first and second temporal gyri [Horsley and Schäfer([40]), Starr([41])]. It may be that the defects in the sense of smell and taste have left their mark on the uncinate gyrus and its neighborhood, if Ferrier's([39]) localization is accepted; but it must be remembered that neither of these senses was entirely wanting, although the former was very defective. I should hesitate, however, to adduce any direct evidence from our case.

While searching for defects it is only fair to keep in mind that the centres for those senses and activities which Laura did retain might have undergone an unusual development. Nevertheless, her finger dexterity in talking would not, I should think, call for unusual control from the cortex and the refinement of touch in her case appears to have been limited to the hands and face. The portion corresponding to the finger and thumb area (see Mills [42—p. 230]) is fairly devel-

oped on the left side and not quite so well on the right, but there is nothing in the gross appearance that is remarkable. Since the interesting work of France([53]) on the *gyrus fornicatus* and the association of this with dermal sensibility in monkeys, I was led to examine this region with such care as the poor condition of this part of the specimen would permit, but with negative results.

Measurements of Cortical Areas.

Every now and then during the present century various investigators have made the attempt to get at the quantity of gray matter in the cerebral cortex, both in man and some of the animals. It has thus far proved impossible to obtain a figure for this portion of the brain which would have the accuracy, for example, of those we possess for its weight, but several approximations have been made which are of some value. The questions which such an examination was designed to answer have not always been briefly formulated and it will be as well to state at once what we expect from it in this case. We wish to know whether those portions of the cortex, which in Laura we suspect are defective and which belong to one hemisphere, will prove to have a less area, when the two hemispheres are compared with one another. We wish to know further whether the total area of the cortex is, in our case, less than the total area of the cortex in a normal brain with which that of Laura might be compared. In the statements just made the term area has been alone used, but of course if we knew at the same time the average thickness of the cortex, then the masses of the cortex might as easily be compared as the areas. These measurements are for the most part neglected in the usual description of specimens, as it takes some time and trouble to make them, and the results are perhaps not proportionate to the expenditure of energy necessary for this. Nevertheless when we get them all together there is quite an array of figures to be found in the literature.

With a view to rendering these results intelligible I shall briefly present some of the objects and conclusions of investigators in this line. R. Wagner([81]) made a number of direct

measurements of the area of the convex (as distinguished from the mesal) surface of specimens in the famous Göttingen collection, which contained among others the brains of Gauss, Fuchs and Dirichlet. He was followed by his son, H. Wagner(44), who measured not only the entire exposed surface but also the length and depth of the sulci, from which the sunken surface, *i. e.*, the portion forming the walls of the sulci, could be calculated, and from these two results the total area of the cortex was obtained. In carrying this task to completion H. Wagner established several relations between portions of the cortex which subsequent investigation has tended to confirm. The main problems which the Wagners had in mind were: first, whether individuals of superior intelligence had the frontal lobes unusually developed; and second, whether, if the individuals were arranged in series according to intelligence, the figures for the areas of the cortex of the respective brains would follow the same order. To the first question the answer was negative; to the second, apparently positive. At the same time the brains of the more intelligent individuals in their series were in general heavier *i. e.* larger than those of the less intelligent and their table might as well be interpreted to mean that in general the larger brains have the larger cortical areas. From the data given by H. Wagner(44) I form the following table to illustrate this last point:—

	Weight of Cerebral Hemispheres, Fresh.	After Hardening in Alcohol.	Total Area of Cortex.
Gauss,	1492 grm.	957 grm.	219588. sq. mm.
Fuchs,	1499 grm.	895 grm.	221005. sq. mm.
Frau,	1185 grm.	864 grm.	204115. sq. mm.
Krebs,	1273 grm.	771 grm.	187672. sq. mm.

It may be noted in passing that Table VIII of H. Wagner (44) is the one that appears in the text books where the figures for the area of the cortex are given. The total area in the original table is expressed as the sum of the areas of the frontal, parietal, occipital and temporal lobes. As a matter of fact it is the sum of these plus the area of the *insula (Stammlappen)*, but the figures for the *insula* have been omitted in the printing of the original table. It thus happens that the figures representing the total area are somewhat larger than the sum of those for the separate lobes as given

in the table. This omission in the original has been perpetuated by the text-books, but so far as I know attention has not previously been directed to it.

Most directly in the line of Wagner's work is that of Jensen([45]) who measured the area of the cortex on six brains of the insane with a view to finding whether they exhibited any peculiarities in this respect. His results were negative.

There are two points in this connection which I desire to emphasize. First, the authors who have undertaken this sort of work have at the same time realized that the thickness, structure and nutrition of the cortex were factors entirely left out of account, and probably of the greatest importance; and second, we have thus far complete measurements only on brains hardened in alcohol in which a decrease in weight of 27%—40% has taken place and consequently no results are at hand to determine by this method the area of the cortex in the fresh normal brain.

Vogt([46]) in his study of microcephalics has given the areas of the exposed surface of the brains. These measurements, however, were taken not on the specimens, but on the casts of the cranial cavity. Of the other methods that of Baillarger([47]) is the most direct, though not the most satisfactory. He separated the cortical surface in the fresh specimen by dissecting out the white matter from the hemispheres. This made it possible to unfold the cortex and thus get at the area by direct measurement. His figure for the total cortical area of the hemispheres is 170000 sq. mm. which he thinks may be correct within 7% for his cases. Besides these there are methods which may be designated respectively as the geometrical, physical and chemical. In a certain sense the measurements of the Wagners and Jensen were geometrical as the cortical surface sunken in the sulci was calculated from the observed length and depth of the sulci. Calori([48]) reduced the exposed surface of the hemispheres to geometrical forms and measured them in that shape, using the device already described for getting the area of the sunken cortex. Giacomini is of the opinion that Calori's method is less exact than that of the Wagners and Jensen. The specimens had been hardened in alcohol. His problem was the varia-

tion in the total area according to the shape of the head. The results which Calori has obtained from a very large number, 41, of Italian brains, measured by his method, are indicated by the following average figures:

Male:	Brachycephalic,	243773 sq. mm.
Male:	Dolicocephalic,	230212 sq. mm.
Female:	Brachycephalic,	211701 sq. mm.
Female:	Dolicocephalic,	198210 sq. mm.

The physical method of getting at similar results is based on the weight of the entire brain, its specific gravity and the specific gravity of the gray and white matter that compose it. This method has been introduced by Danilewsky([49]). The result is the percentage of gray and white matter in a given specimen. If now a certain proportion of the gray matter is assumed to belong to the cortex we can obtain the mass of the cortex and in turn assuming a certain average thickness for the same we can calculate the area. Omitting all detail, Danilewsky([49]) found:

For encephalon weighing 1240 grm., total cortical surface, 158800 sq. mm.
" " " 1324 " " " " 169200 " "

As will be seen these figures fall below any that have thus far been given.

In the chemical method, so called, the percentage of water is determined instead of the specific gravity and from data thus obtained the mass or area of the cortex can be determined. More or less complete data for the percentage of water in the gray and white matter of the brain have been furnished by Bourgoin([50]), Desprez([51]) and Forster([52]). Giacomini takes the view that of the last two methods the chemical one is the more exact. At his suggestion DeRegibus([17—p. 276]), examined several brains and obtained the following figures for the area of the cortex:

1.	Single hemisphere,	128000 sq. mm.
2.	Both hemispheres,	278940 sq. mm.
3.	" "	245160 sq. mm.
4.	" "	217472 sq. mm.

The original weights of the brains are not given.

The figures obtained by Baillarger([47]) and by those authors who have used the physical and chemical methods apply to the fresh brain, having its normal size; whereas all the other figures apply to brains shrunken by alcohol. At the moment

we have no means of making the corrections required, but it would be fair to expect that measurement on the fresh brain would show a larger area than those on alcoholic brains. If that is a true inference, then it is not a little curious that of these authors just mentioned only DeRegibus presents figures which are at all comparable with those of the Wagners, Jensen and Calori, the figures from the other observers being smaller.

I pass now to the measurements of our own specimen. The questions to be answered have already been stated: 1st. To determine any differences between the areas of special regions in the two hemispheres. 2nd. The total area of the cortex.

Method of Making Measurements. Investigators have covered the exposed surface of the cortex with squared paper, tin foil, gold-leaf or something of the sort, and then by computing the number of these squares required to cover a given region have calculated the area. In this instance I moistened thin sheets of gelatine until they were flexible; these were then laid on the surface and the outlines of the exposed portions of the gyri traced on them by means of India ink. The area of a region having thus been transferred to the gelatine it was removed, a copy of it taken on tracing paper and numbered. The same area was enclosed by a line on the plaster cast and given the same number, thus each region was recorded. The gelatine sheet was placed over a piece of standard paper ruled in squares 2 mm. on each side. Under a lens magnifying 6 diameters the number of squares enclosed by the outline was enumerated and reduced to millimeters. The method proved quite practicable and accurate. In getting the area from the gelatine sheet measurements were made to square millimeters.

The length of the sulci was taken with compasses where that was permissible, but usually with a strip of tin foil marked in centimeters. The fractions of a centimeter were taken with compasses and read on a millimeter scale. The depth of the sulci was taken with a fine hard rubber probe, a trifle enlarged at the tip so that it had there a diameter of 1.3 mm. On this a button of pith which slipped easily served to mark the dis-

tance to which the probe was inserted, and this distance was read off on a millimeter scale. The majority of the sulci were sounded every centimeter, short ones at lesser intervals. The calculations of the sunken surface were made on the assumption that the lines representing the length and depth formed with one another rectangular figures. Jensen's([45]) argument for considering these figures zonal segments, on the convex surface at least, was at the time unknown to me, but I think that the error introduced by the method used has in our case largely balanced out, since the direct measurement of the depth of the sulci was constantly too small. The figures were not summed until all the data were collected and they have not been manipulated in any way save as I shall in a moment state. The sums thus obtained are as shown in Table I.

TABLE I.

Total Surface, Sunken and Exposed. (Not corrected.)

	Left.	Right.
Insula,	1760. sq. mm.	2026.5 sq. mm.
Frontal lobe,	27624.5 sq. mm.	29584. sq. mm.
Occipital lobe,	3824.5 sq. mm.	3604.8 sq. mm.
Residual portions,	51056.7 sq. mm.	47452. sq. mm.
	84265.7 sq. mm.	82667.3 sq. mm.
Absolute difference =	1398.4 sq. mm.	
In percentage =	1.8 %	

As will be seen the result shows the total cortical surface nearly alike in both hemispheres.

By "exposed surface" is meant that portion which does *not* contribute to the walls of the sulci; by "sunken surface" that which does thus contribute. The portion of the *insula* and the *operculum* which would, under this definition, be called exposed is nevertheless counted as part of the sunken surface from its position, both in the calculations for the surface of the frontal lobe and for the entire hemisphere. In the tables for the *insula* alone a distinction is made between the sunken surface, as defined, and the other portion, which to avoid ambiguity is there called "convex surface." The total figure for the sunken surface of the frontal lobe or a hemisphere contains, then, the not-sunken or convex surface of the *insula* and also the *operculum* which, by the way,

showed no sulci so far as it was in contact with the *insula*. As neither of these contribute to form the walls of sulci they are subtracted from the total "sunken surface" before the average depth of the sulci is calculated. Further, in getting the average depth of the sulci, proper correction is made for those instances where the sulcus had been considered to have but one wall, as in the case of the callosal and the cephalic portions of the Sylvian fissures.

The Sylvian fissure is considered to start at the lateral end of the *vallecula Sylvii*. The limitation of the *insula* is by the *sulcus circularis* (Schwalbe). The frontal lobe is limited by the *fissura Sylvii*, the *fissura centralis*, and the *fissura subfrontalis* (Eberstaller). The limitations of the occipital lobe have been previously described as formed by the *sulcus parieto-occipitalis*, *fissura calcarina*, *sulcus occipitalis lateralis*, and *sulcus occipitalis anterior*.

Finally with regard to the corrections in the figures obtained by direct measurement. Such correction has been made for the depth of the sulci only. This affects in the results, of course, the average depth of the sulci, the area of the sunken surface and the total area. The correction has been made by adding 25% to the observed depth of the sulci, that is, the observed depths were considered to represent 75% of their real value, and were increased so as to represent 100%.

A word of explanation is here needed. The facilities for getting the true depth of the sulci in a brain hardened in potassium bichromate are much less than in the case where the hardening has been effected by alcohol. Sulci in our case could not be opened up without fear of injury to the specimen and the resistance by which one inferred that the bottom of the sulcus had been reached was often caused by the approximation of the walls at some distance above the bottom. This error was neglected, however, until the measurements were complete, on the assumption that it would be the same for both sides. The figures obtained, Table I, justified this assumption and what we have to say concerning the relative development of the hemispheres and their sub-divisions can be equally as well based on the original as on the corrected figures; but when

we desire to compare the total area in our case with that found by other investigators as well as the relations of the exposed and sunken surface, it is absolutely necessary to use the corrected figures. The correction was obtained by measuring sulci in sections of the hemispheres and noting the difference between the true depth and the depth as obtained by the probe. This difference approximated on an average 25%, being a trifle over that figure. It is with regret that I introduce this modification of the results, but certain it is that without the correction the absolute figures would have fallen far below the truth. One point more; we are dealing here with a brain that has swollen in hardening. What the total amount of variation in the area of surface thus produced is, I cannot say, but I see no reason to think that the relations of regions at the surface of the brain have been altered. The portions which did not harden and therefore did not swell were the ental ones, but the cortex throughout was exposed to the action of the fluid in much the same way and does not, I believe, show any distortion that is due to irregularities in the preservation.

Insula.

I may be permitted to state here that the descriptions of the various regions were written before the following figures relating to them had been tabulated, and that in comparing the figures with the previous description I am comparing independent observations.

Defective development of the centre for articulate speech in the left hemisphere has been already described. When defective development occurs here the *insula* is often reported as sharing in the defect. The following, Table II, shows the relations for the *insula*. This table, as well as all those that follow, is corrected in the manner above mentioned.

TABLE II.

Insula. (Corrected.)

	LEFT.	RIGHT.
Greatest length,	55. mm.	66. mm.
Greatest width,	30. mm.	33. mm.
Convex surface,	1488. sq. mm.	1625.5 sq. mm.
Sunken surface,	363. sq. mm.	548. sq. mm.
Total length of sulci,	88. mm.	83. mm.
Average depth of sulci,	2.0 mm.	3.3 mm.

It appears from this that the left insula is less well developed than the right in every way except the length of the sulci, in which it is slightly superior.

Frontal Lobe.

Next in order we take the frontal lobe as above defined.

The frontal lobe is bounded by sulci, and these stand in the table as limiting sulci. One half the sunken surface which lines these sulci is designated as the limiting sunken surface; the other half of course belongs to the lobes bounding the frontal lobe. The area bounded by these limiting sulci is the included area. In this case our interest is in the included area.

TABLE III.

Frontal Lobe. (Corrected.)

	LEFT.	RIGHT.
Total exposed surface,	11320. sq. mm.	**12326.** sq. mm.
Limiting sunken surface,	**5920.4** sq. mm.	5020.2 sq. mm.
Included sunken surface,	15818.4 sq. mm.	**17994.** sq. mm.
Length of limiting sulci,	**449.** mm.	411. mm.
Length of included sulci,	1051. mm.	**1117.** mm.
Average depth of limiting sulci,	**13.0** mm.	12.1 mm.
Average depth of included sulci,	7.4 mm.	**8.** mm.

Considering the included area and the figures relating to it, we find the left lobe inferior to the right in every point; to this inferiority the suspected *gyrus frontalis inferior* is assumed to contribute largely. It would seem simpler to compare measurements of this gyrus on both sides, but the difficulty of bounding it *cephalo-ventrally* has deterred me from trying to make the comparison. The deficiency in the figures relating to the limiting portions on the right side is in part due to the less elaborate development of the *fissura subfrontalis* (Eberstaller)—the *sulcus calloso-marginalis* of Ecker.

Occipital Lobe.

In the earlier description it was brought out that the right occipital lobe and especially the right *cuneus* were poorly developed. Table IV shows the results of measurements.

TABLE IV.

Occipital Lobe. (Corrected.)

	LEFT.	RIGHT.
Total exposed surface,	1660.5 sq. mm.	1302. sq. mm.
Exposed surface of cuneus,	608. sq. mm.	412. sq. mm.
Limiting sunken surface,	1957.2 sq. mm.	1847.7 sq. mm.
Included sunken surface,	928. sq. mm.	1356. sq. mm.
Length of limiting sulci,	133. mm.	137. mm.
Length of included sulci,	108. mm.	116. mm.
Average depth of limiting sulci,	14.6 mm.	13.4 mm.
Average depth of included sulci,	4.2 mm.	5.7 mm.

Here again the measurements support to some extent the previous observations. The total exposed surface, and the exposed surface of the *cuneus* are both less on the right side. But when we come to compare the included sunken surfaces on the two sides the right is superior, and if we sum the total exposed and sunken surface for the two sides we find it:

On Left Side.	On Right Side.
2588.5 sq. mm.	2658. sq. mm.

That is, it results to the advantage of the right side. The disturbance then which caused the peculiarities of the right lobe did not materially alter the cortical development on the two sides. This would, for one thing lead us to regard the *cuneus* where the difference between the two sides is striking with especial care. As the table shows, the exposed surface of the *cuneus* on the left side is the greater. If we add to each exposed surface the sunken surface for this special region, *i. e.*, *cuneus*, we get the following:

	LEFT.	RIGHT.
Exposed surface, cuneus,	608 sq. mm.	412 sq. mm.
Sunken surface, cuneus,	376 sq. mm.	428 sq. mm.
Total surface, cuneus,	984 sq. mm.	840 sq. mm.

This indicates the total cuneal surface as smaller for the more irregular right side, which is what we might expect if the visual centre is here located. For the rest of the occipital lobe there appears to have been that compensatory growth by which the portions about the *cuneus* developed more generously as the *cuneus*, itself somewhat arrested, offered less resistance to their expansion.

Residual Portion.

What remains after the *insula*, frontal and occipital lobes have been considered, I call the "residual portion." In itself

it has no special interest for us at the moment. The figures are given in Table V.

TABLE V.

Residual Portion. (Corrected.)

	LEFT.	RIGHT.
Total exposed surface,	18842. sq. mm.	19037.2 sq. mm.
Limiting sunken surface,	7877.6 sq. mm.	6867.9 sq. mm.
Included sunken surface,	35074.9 sq. mm.	31022. sq. mm.
Length of limiting sulci,	582. mm.	548. mm.
Length of included sulci,	1619. mm.	1613. mm.
Average depth of limiting sulci,	13.3 mm.	12.4 mm.
Average depth of included sulci,	10.8 mm.	10. mm.

Having thus presented the data for all portions of the hemispheres it remains to cast them in the form of tables so that, as far as possible, they may be compared with the results of others, and we may thus determine something of the relative cortical development in this case. Table VI gives the total exposed surface according to the limitations previously stated.

TABLE VI.

Total Exposed Surface.

	LEFT.	RIGHT.
Insula,	———	———
Frontal lobe,	11320. sq. mm.	12326. sq. mm.
Occipital lobe,	1660.5 sq. mm.	1302. sq. mm.
Residual portion,	18842. sq. mm.	19037.2 sq. mm.
Total,	31822.5 sq. mm.	32665.2 sq. mm.
Absolute difference,		842.7 sq. mm.
Percentage difference,		2.6 %

Table VII gives in the same way the total sunken surface.

TABLE VII.

Total Sunken Surface. (Corrected.)

	LEFT.	RIGHT.
* Insula,	1851.0 sq. mm.	2173.5 sq. mm.
Frontal lobe,	21738.8 sq. mm.	23014.2 sq. mm.
Occipital lobe,	2885.2 sq. mm.	3203.7 sq. mm.
Residual portion,	42952.5 sq. mm.	37889.9 sq. mm.
	69427.5 sq. mm.	66181.3 sq. mm.
Absolute difference,	3246.2 sq. mm.	
Percentage difference,	4.9 %	

* It will be recalled that for our purpose the *insula* is not considered to have an exposed surface.

TABLE VIII.

Total Surface, Sunken and Exposed. (Corrected.)

	Left.	Right.
Insula,	1851.0 sq. mm.	2173.5 sq. mm.
Frontal lobe,	33058.0 sq. mm.	35340.2 sq. mm.
Occipital lobe,	4551.7 sq. mm.	4505.7 sq. mm.
Residual portion,	61794.5 sq. mm.	56927.1 sq. mm.
Total,	101256.0 sq. mm.	98946.5 sq. mm.
Absolute difference,	2309.5 sq. mm.	
Percentage difference,	2.3 %	

This Table VIII gives the total figures which I consider final for this specimen. To prevent any possible misunderstanding I may state again that Table I, which gives the original figures before they were corrected, is presented to show on what basis the corrections were to be made. And though it is possible that the two tables may be confused, I hope by this explicit statement to prevent such a complication, and make it plain that Table VIII only is the one to be used in comparison with the figures obtained by other authors.

In connection with Table VIII, I have to call attention to the figures for the total surface of the *insula* and frontal lobes of the left side which still remain smaller, whereas the occipital lobe is slightly larger on the left side. On the whole the area of the left hemisphere is greater, and I associate that with the fuller development of the caudal portions of this hemisphere. (See Fig. III.)

The length of sulci is shown in Table IX, and as will be seen the left hemisphere is a trifle inferior in this measurement. The limiting sulci are of course counted but once, so that if their length is given for the frontal and occipital lobes then the residual portion is to be credited with the included sulci only.

TABLE IX.

Total Length of Sulci.

	Left.	Right.
Insula,	88 mm.	83 mm.
Frontal lobe, limiting sulci,	449 mm.	411 mm.
Frontal lobe, included sulci,	1051 mm.	1117 mm.
Occipital lobe, limiting sulci,	133 mm.	137 mm.
Occipital lobe, included sulci,	108 mm.	116 mm.
Residual portion, included sulci,	1619 mm.	1613 mm.
	3448 mm.	3477 mm.

Table X exhibits the average depth of the sulci for each hemisphere. The average depth of the sulci is obtained in the following manner: From the total sunken surface as previously given, the areas of the *operculum* and convex surface of the *insula* are subtracted. The areas for the *sulcus callosi* and the portion of the *gyrus frontalis inferior* which forms the dorsal wall of the *fissura Sylvii*, which have not been doubled in estimating the sunken surface, are added to this remainder. The sum is then divided by two, thus giving the area of one side of all the sulci. This divided by the total length of sulci gives the average depth. This process is carried out in Table X.

TABLE X.

Average Depth of Sulci. (Corrected.)

	LEFT.	RIGHT.
Total sunken surface,	69427.5 sq. mm.	66181.3 sq. mm.
Less sum of opercular and convex insular surfaces,	2426.0	2663.
	67001.5 sq. mm.	63518.3 sq. mm.
Plus callosal wall	1037.0 sq. mm.	1037.0 sq. mm.
Plus dorsal wall fiss. Syl.	827.0 sq. mm.	400.0 sq. mm.
One-half of this total	68865.5 sq. mm.	64955.3 sq. mm.
equals	34432.7 sq. mm.	32477.6 sq. mm.
Dividing this last figure by	3448.	3477.
Gives average depth of Sulci	9.9 mm.	9.3 mm.

The table explains itself I think without further comment, except the difference between the figures for the dorsal wall of the *fissura Sylvii* on the two sides, which is due to the fact that the method of measurement was not the same in both cases.

Before we make comparison of those figures which apply to the entire hemispheres, several other numerical relations may be noted. The surface of the frontal lobe in per cent. of the total surface is found to be:

	LEFT.	RIGHT.
Total surface,	100	100
Frontal lobe, total surface,*	32.5	35.8

We may also express the relations of the exposed and sunken surface in the two hemispheres:

*Our limits of the frontal lobe enclose a smaller region than those of the other authors who have given figures.

	LEFT.	RIGHT.
If total exposed surface =	1.	1.
Then total sunken surface =	2.18	2.02

This relation of the exposed to the sunken surface is that which has been found by others, namely, the sunken surface is on the average very slightly more than twice the exposed surface.

Finally H. Wagner(44) devised a formula by which the exposed surface of the brain could be calculated from its several diameters. Applying this formula to our specimen we find by calculation a figure which is some 25% larger than that obtained by observation. Evidently the swelling of the brain and the consequent gaping of the sulci renders this formula inapplicable in our case.

It remains now to determine what peculiarities these figures obtained from our specimen show when compared with the figures from other authors, always keeping in mind that the latter figures used for comparison were obtained from shrunken specimens, whereas ours is swollen. We shall use for comparison the data furnished by H. Wagner(44), Jensen(45) and Calori(48). From the first the figures for the "woman" are used. From the second those for "Rockel," female, insane, and from the last those for brachycephalic females, three in number.

TABLE XI.

Total Surface.

Weight of Fresh Encephalon.		LEFT.	RIGHT.	SUM.
1204 grm.	Laura,	101256. sq. mm.	98946.5 sq. mm.	200202.5 sq. mm.
*1304 grm.	Woman,	102742. sq. mm.	102373. sq. mm.	205115.0 sq. mm.
1065 grm.	Rockel (female, insane),	74615. sq. mm.	74523. sq. mm.	149138.0 sq. mm.
1236 grm.	Brachycephalic females.			245260. sq. mm.
1151 grm.				195684. sq. mm.
1056 grm.				194160. sq. mm.

The total figure for Laura, though her brain is swollen, is somewhat under that found by Wagner, and also under the average taken from the two brains of Calori with which it may be fairly compared, but above that of Jensen. The

* Figures for area corrected from H. Wagner's(44) table. As I understand Wagner, the fresh weight of this brain, which he gives as 1185 grm., applies to the hemispheres alone. 1304 is the estimated weight of the entire encephalon to which these hemispheres belonged.

small brain weight and the mental condition of the patient in Jensen's case must however be considered. I see here no greater variation than occurs in the full tables of these authors. We may conclude therefore that the total area of Laura's brain, if at all peculiar, was small for its weight. Comparison for total length of sulci and their average depth can be made only with the first two, as Calori does not give his figures on this point.

TABLE XII.

Total Length of Sulci and Average Depth.

Name.	LEFT.		RIGHT.		SUM.	
	Length.	Av. Depth.	Length.	Av. Depth.	Length.	Av. Depth.
Laura,	3448. mm.	9.9 mm.	3477. mm.	9.1 mm.	6625. mm.	9.5 mm.
Woman,	3349. mm.	9.88 mm.	3189. mm.	10.48 mm.	6538. mm.	10.14 mm.
Rockel,	2870. mm.	——	2834. mm.	——	5704. mm.	9.08 mm.

It appears that, whereas the length of the sulci is greater in Laura than in those with whom she is compared, the average depth in less than that of the woman and more than that of Rockel. At the same time both length and depth are well within the limits found by these authors for other brains.

The relative development of the frontal lobe is something to which a certain historical value, at least, attaches. The frontal lobe as we define it is somewhat smaller than that of Wagner and Jensen as they include that portion of the *gyrus fornicatus* which extends caudad as far as the *præcuneus*. If we include this region so as to make our results comparable with theirs we have the figures given in the next table.

TABLE XIII.

Relative Development of Frontal Lobe, given in Percentage of the Total Surface.

	LEFT.	RIGHT.	Average for Both Hemispheres.
Laura,	36.8	39.9	38.3
Woman,	40.	41.	41.
Rockel,	38.3	40.9	39.6

When the comparison is made in this way Laura is seen to be slightly inferior to the other two. An examination of the tables shows this to depend mainly on the smaller average depth of the sulci. The inferiority of the left side is manifested here again. In general then we may say that so far as these measurements are concerned, Laura's brain differs from other brains with which it may be compared to

4

no remarkable degree, and the difference can in part at least, be explained by the failure of certain portions of the brain to develop completely. The determination of the mass of the cortex must await the measurement of its thickness, and that together with other observations is reserved for a second article.

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Explanation of Plates.

The Figures were drawn from photographs with the aid of a pantograph. Their size is approximately that of the hardened specimen. The lines indicating the sulci represent the middle of the lines marking sulci in the photograph. No indication of the gape of the sulci is given, except in the case of the *fissura Sylvii*. Where the sulcus gapes widely this method of representation makes the gyri on either side appear broad, and it is of course not possible to tell in these figures just how the space between any two sulcal lines is filled. The more constant sulci are indicated by heavy lines. The names are arranged alphabetically according to the initial letter of the abbreviation.

- *C.* Fissura centralis.
- *Ca.* Fissura calcarina.
- *ctr.* Sulcus centralis transversus.
- *d.* Sulcus diagonalis.
- *f 1.* Sulcus frontalis superior.
- *f 2.* Sulcus frontalis inferior.
- *f 3.* Sulcus frontalis medius.
- *fm 1.*, *fm 3.* Sulcus fronto-marginalis.
- *ip.* Sulcus interparietalis.
- *occ. ant.* Sulcus occipitalis anterior.
- *occ. lat.* Sulcus occipitalis lateralis.
- *pci.* Sulcus præcentralis inferior.
- *pcs.* Sulcus præcentralis superior.
- *po.* Fissura parieto-occipitalis.
- *r.* Sulcus radiatus.
- *rtc. i.* Sulcus retrocentralis inferior.
- *rtc. s.* Sulcus retrocentralis superior.
- *rtc. tr.* Sulcus retrocentralis transversus.
- *S 1.* Fissura Sylvii.
- *S 2.* Ramus anterior ascendens fissuræ Sylvii.
- *S 3.* Ramus anterior horizontalis fissuræ Sylvii.
- *S 1. asc.* Ramus posterior ascendens fissuræ Sylvii.
- *sft.* Fissura subfrontalis.
- *t 1.* Sulcus temporalis primus.
- *t 2.* Sulcus temporalis secundus.
- *t 3.* Sulcus temporalis tertius.
- *t 4.* Sulcus temporalis quartus.
- *t 1. asc.* Ramus ascendens sulci temporalis primi.
- *t 2. asc.* Ramus ascendens sulci temporalis secundi.
- × Points at which the specimen was cut across.

PLATE I.

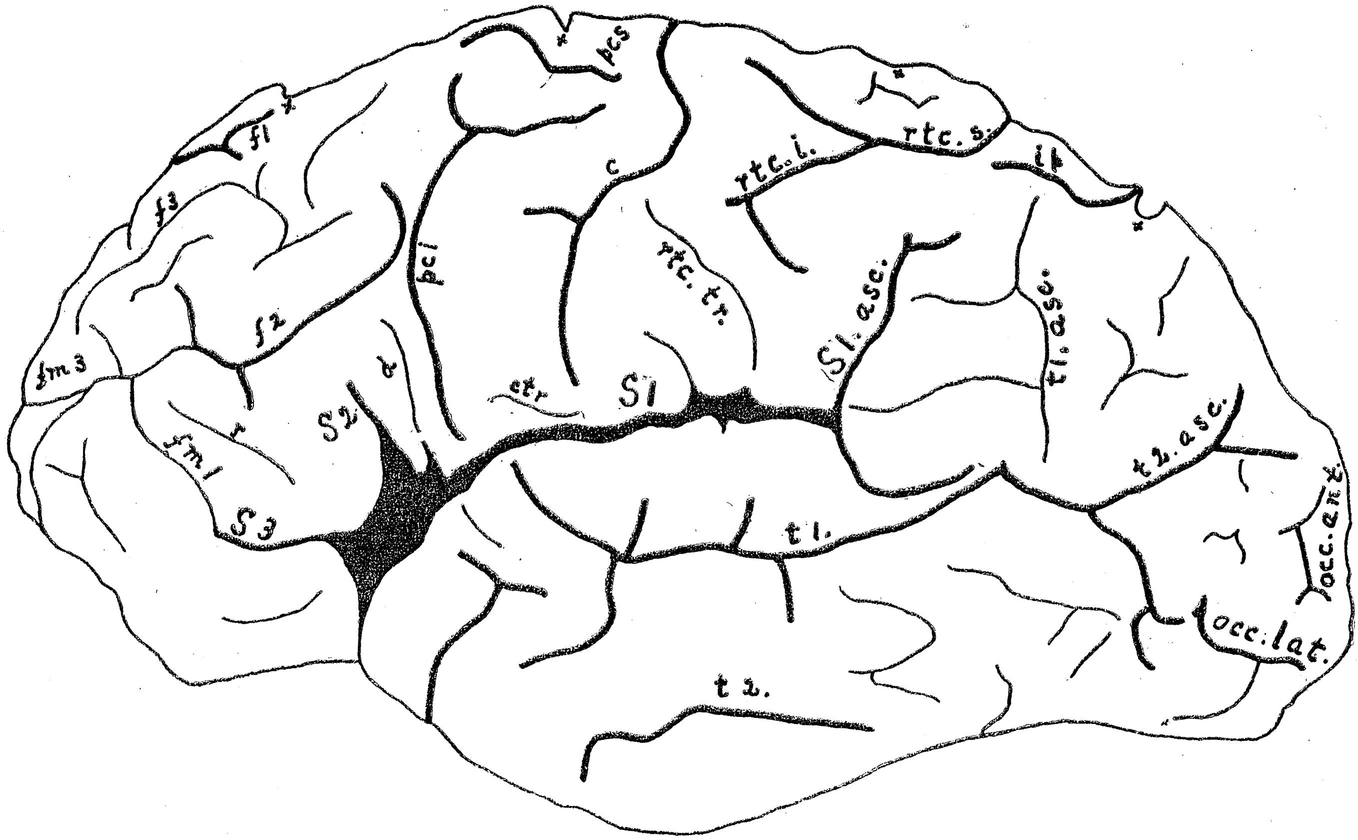


FIG. I. Left hemisphere, seen from the side and somewhat from below.

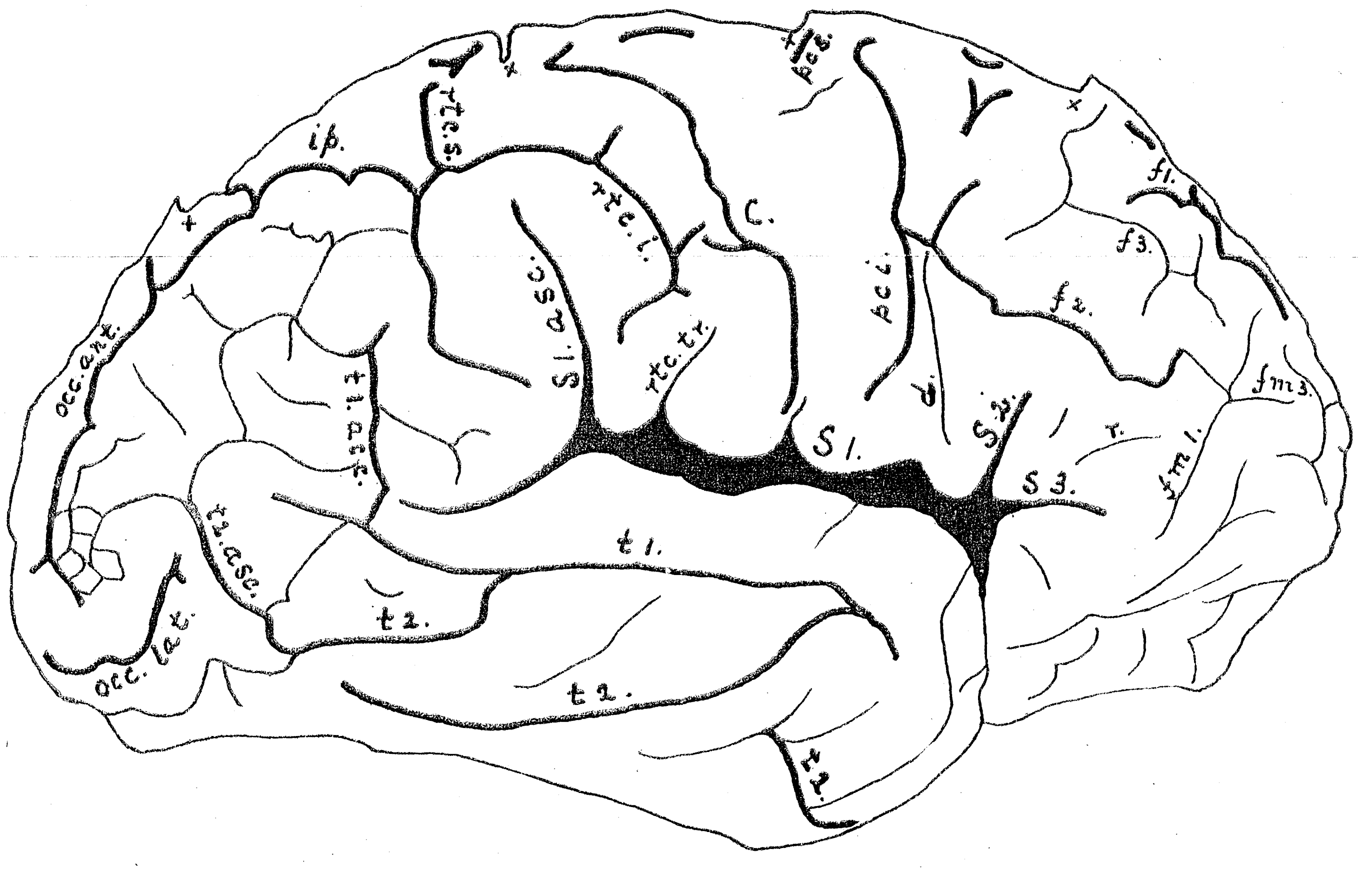
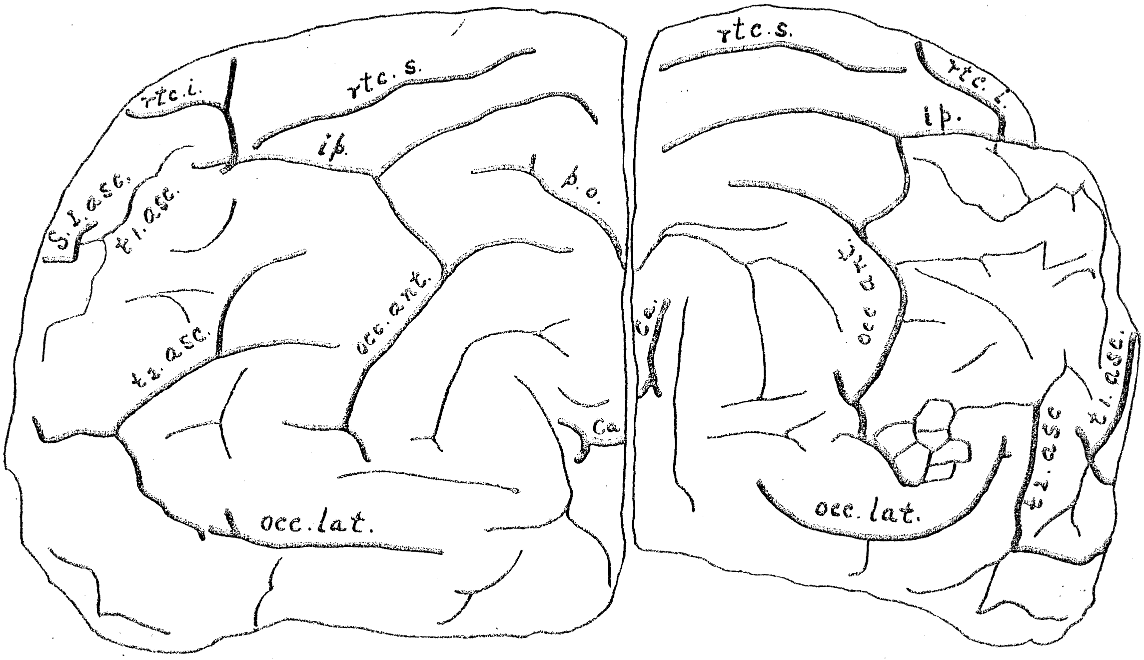


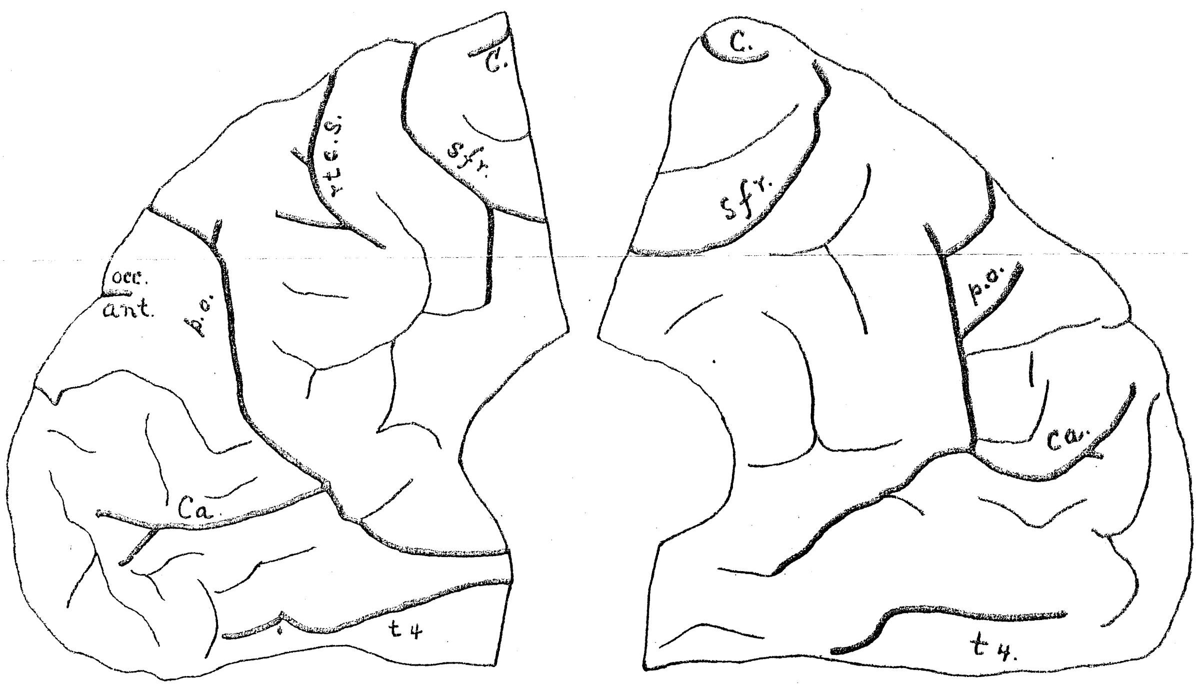
FIG. II. Right hemisphere, seen from the side.

PLATE II.



LEFT. RIGHT.

FIG. III. Both hemispheres seen from behind, showing principally the occipital region. The difference between the hemispheres is exaggerated by the fact that they are viewed rather more from the left side.



LEFT. RIGHT.

FIG. IV. Mesal surface of both hemispheres, to show the region of the cunei and præcunei